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13. ABSTRACT *(Maximum 200 words)*

Our work was focused on electronic transport, particularly the importance of quantum effects, and on the reliability of semiconductor devices with ultra-submicrometer channel length.
We have applied our quantum transport model based on Schroedinger Equation Monte Carlo simulation to the problem of impact ionization. We have shown that collision broadening lowers the threshold of impact ionization.
In the area of reliability, we have suggested and simulated a new method to avoid latent failures of ultra-submicrometer CMOS devices.

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List of Manuscripts

1. Leonard F. Register and Björn Fischer, "Collision Broadening Through Sequences of Scattering Events: Theory, Consequences and Modeling Within Semiclassical Monte Carlo," to be published in, Selected Topics in Electronics and Systems (Book Chapter).

2. W. Chen, Q. Ouyang, L. F. Register and S. K. Banerjee, "Quantum Effects along the channel of Ultra-scaled Si-Based MOSFETs," IEDM 2000, 291.

3. W. Chen, L. F. Register, L. F. Register and S. K. Banerjee, "Simulation of Quantum Effects along the channel of Ultra-Scaled Si-Based MOSFETs, IEEE TED, in review.

4. X. Zheng, W. Chen, M. Stroscio, and L. F. Register, "Quantum Transport Simulation of Carrier Transport and Energy Relaxation within Tunnel Injection Lasers," abstract accepted for the 2001 International Workshop on Computational Electronics (IWCE-8).

5. A. Haggag, W. McMahon, K. Hess, K. Cheng, J. Lee, and J. Lyding, "High-Performance Chip Reliability from Short-Time-Tests," Proceedings of IEEE International Reliability Physics Symposium (IRPS, 2001), Orlando, Florida, April 30-May 3, 2001.

6. W. McMahon, A. Haggag, and K.Hess, "Modeling Failure Modes for Submicron Devices," Proceedings of International Symposium on Physical and Failure Analysis of Integrated Circuits, (IPFA'2001), Singapore, July 9-13, 2001.

7. A. Haggag, W. McMahon, K. Hess, K. Cheng, J. Lee, and J. Lyding, "Sub-linear Time-Dependence of Hot-Carrier Degradation in Deep-Submicron CMOS Chips: A New Analytical Formula," Proceedings of IEEE Microelectronics Reliability and Qualification Workshop (MRQW' 2001), Glendale, California, October 31-November 1, 2000.

8. K. Hess, A. Haggag, W. McMahon, K. Cheng, J. Lee, and J. Lyding, "The Physics of Determining Chip Reliability," IEEE Circuits & Devices, pp. 33-38, May 2001.

Scientific personnel supported by the UT Subcontract during this period were:

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Scientific Progress and Accomplishments

During this final period of the contract/subcontract we have made progress in both quantum and semiclassical transport modeling, with applications to both III-V and Silicon-based devices. We also have made considerable progress in the physics of device reliability.

A) Electronic Transport

During previous interim periods, we developed a new semiclassical Monte Carlo algorithm for modeling the effects of collision broadening on carrier transport and scattering. In publication (1) above we provided a more detailed explanation of the theory behind this new algorithm and, among other things, applied it to the modeling of impact ionization. It was shown that collision broadening lowers but does not eliminate the threshold for impact ionization, producing simulated impact ionization coefficients for holes in Silicon that accurately track experimental results as a function of field. To the best of our knowledge, this is the first time this has been achieved via first-principles ab initio calculations. Publications (2) and (3) represent exploratory simulations of quantum transport effects in silicon and silicon-based heterostructure devices. Specifically, using our Schrödinger Equation Monte Carlo (SEMC) method that bridges the gap between quantum and classical transport, we began to search for where, in terms of device size, that transition becomes important. We found that semiclassical models of transport *along the length of the channel* (although perhaps included quantum corrections for channel-normal quantum confinement effects) should remain reliable down to and perhaps below the 10nm channel lengths. More recently, in continuing work we found that even significantly after a majority of the transport becomes coherent, physically and quantitatively accurate modeling of the scattering remains crucial and the various scattering processes must still be differentiated as in semiclassical Monte Carlo. The abstract for publication (4) was submitted and accepted during this contract period, while the actual work bridges over into a new ARO contract. For this work we are studying/will study carrier transport and capture within tunnel injection lasers, considering effects including tunneling, resonant scattering, and non-parabolic band structures.

B) Physics of Device Reliability

Continuing our work on device reliability related to hydrogen release and the improvement by deuterium, we have made a basic discovery. If the channel length of CMOS devices becomes smaller than 0.1μm, then statistical fluctuations of the defect creation energy begin to matter a great deal. It becomes then probable to find on a chip devices that have enough defects with low creation energy to have a life time considerably below the average. These devices are therefore "lemons" or latent failures. We have simulated such latent failures and found that very short time stress tests can give results for the number of latent failures and also how they can be avoided. We believe that these findings will be very significant for the reliability of the next device generations. Details can be found in publications (5)-(7) above. A summary and review is given in publication (8).